Effects of Acute Exposures to Carbon Dioxide upon Cognitive Functions

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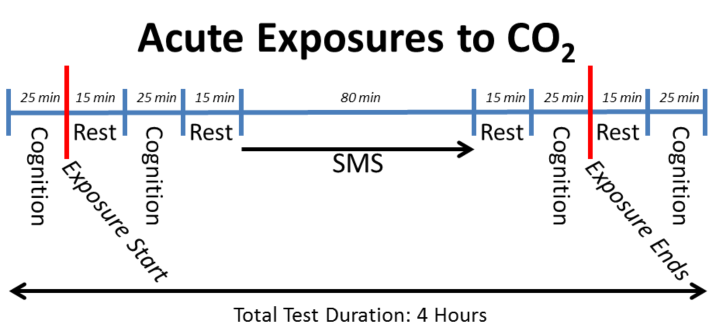
Carbon dioxide (CO2) originates from human metabolism and typically remains about 10-fold higher in concentration on the International Space Station (ISS) than at the earth's surface. There have been recurring complaints by crew members of episodes of "mental viscosity" adversely affecting their performance, and there is evidence from the ISS that associates CO_2 levels with reports of headaches by crewmembers [1], [2]. Consequently, flight rules have been employed to control CO_2 below 3 mm Hg, which is well below the existing Spacecraft Maximum Allowable Concentration (SMAC) of 10 mm Hg for 24-hour exposures, and 5.3 mm Hg for exposures of 7 to 180 days [3]. Headaches, while sometime debilitating themselves, are also symptoms that can provide evidence that physiological defense mechanisms have been breached [4], and there is evidence that CO_2 has effects at levels below the threshold for headaches. This concern appears to be substantiated in reports that CO_2 at concentrations below 2 mm Hg substantially reduced some cognitive functions that are associated with the ability to make complex decisions in conditions that are characterized by volatility, uncertainty, complexity, ambiguity, and delayed feedback [5], [6]. These are conditions that could be encountered by crews in off-nominal situations or during the first missions beyond low earth orbit. Therefore, we set out to determine if decision-making under volatile, uncertain, confusing and ambiguous circumstances, where feedback is delayed or absent, is correlated with low levels of CO_2 during acute exposures (several hours) in crew-like subjects and to determine if additional cognitive domains are sensitive to concentrations of CO2 at, or below, current ISS levels by using a test battery that is currently available onboard ISS.

We enrolled 22 volunteers (8 females, 14 males) between the ages of 30-55 (38.8 ± 7.0) years whose training and professional experience reflect that of the astronaut corps. Subjects were divided among 4 study groups. Exposures occurred in the 20-foot environmental chamber in Bldg 7 at JSC. Each group was exposed to each of four concentrations of CO2 (600, 1200, 2500, and 5000 ppm), and the exposure order was balanced across the groups which were randomly assigned to 4 possible complete exposure orders. Study participants and investigators were blinded to the exposure order. Each exposure lasted 4 hours and occurred on the same day each week for 4 consecutive weeks. Testing included the Strategic Management Simulation (SMS) methodology [5] and the *Cognition* [7] battery of psychometric measures that are being utilized aboard the ISS. Subjects participated in a familiarization session one week prior to the start of exposure sessions. Each exposure session followed the schedule noted in Figure 1 below. On the morning of each exposure, subjects completed the *Cognition* battery in a conference room at indoor ambient CO2 levels. Subjects then entered the exposure chamber and were acclimated to the environment for 15 minutes before completing another round of the *Cognition* battery. After a 20 minute rest, subject completed the ~80 minute SMS. Subjects were allowed another 20 minute rest period before completing the final *Cognition* test battery in the exposure chamber. Subjects then returned to the conference room where they completed one final round of *Cognition*. Data from both testing methodologies are currently being analyzed and will be presented. Study investigators have not yet been unblinded to the coded exposure concentrations, but preliminary results suggest differences.

Figure 1. Test procedure



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